

Method of manufacturing a cooling plate and a cooling plate manufactured with this method

The present invention concerns a method of manufacturing a cooling plate and a cooling plate manufactured with this method.

Background of the Invention

Cooling plates, also called "staves", have been used in blast furnaces for over a hundred years. They are arranged on the inside of the furnace shell and have internal coolant ducts, which are connected to the cooling water circuit of the furnace. Their surface facing the interior of the furnace can be lined with a refractory material. Connection pipe-ends for cooling water are arranged on the rear side of the cooling plate and lead out in a sealed manner through the furnace shell. Cooling passages of a plurality of cooling plates are connected in series and are connected to a cooling water circuit of the furnace by means of these connection pipe-ends which lead out of the furnace shell.

Until some years ago, most cooling plates in blast furnaces were cast iron cooling plates. There are different methods for manufacturing such cast iron cooling plates. According to a first method, a mould for casting a cooling plate body is provided with one or more sand cores for forming the internal coolant ducts. Liquid cast iron is then poured into the mould. This method has the disadvantage that the mould sand is difficult to remove from the cooling ducts and/or that the cooling duct in the cast iron is often not properly formed or not tight enough. In order to avoid the aforementioned disadvantages, it has been suggested to arrange preformed steel pipes in the mould and to pour the liquid cast iron around the steel pipes. However, these cast iron cooling plates with steel pipes have not proved satisfactory. Indeed, due to carbon diffusion from the cast iron into the steel pipes, the latter become brittle and may crack.

As an alternative to cast iron cooling plates, copper and recently steel cooling plates have been developed. Different production methods have been proposed for copper "staves".

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Initially an attempt was made to produce copper cooling plates by casting in moulds, the internal coolant ducts being formed by a sand core in the casting mould. However, this method has not proved to be effective in practice, because the cast copper plate bodies often have cavities and porosities, which have an extremely negative effect on the life of the plate bodies. The mould sand is difficult to remove from the cooling ducts and the cooling duct in the copper is very often not properly formed.

GB-A-1571789 suggests to replace the sand core by a pre-shaped metal pipe coil made from copper or high-grade steel when casting the cooling plates in moulds. The coil, which forms a spiral coolant duct, is arranged in the casting mould and the liquid copper is poured around the coil. This method has also not proved effective in practice, because neither cavities and porosities in the copper plate body, nor problems at the interface between the metal pipe and the copper solidifying in the mould can be effectively prevented.

A cooling plate made from a forged or rolled copper slab is known from DE-A-2907511. The coolant ducts are blind holes introduced by mechanical drilling in the rolled copper slab. The blind bores are sealed off by soldering or welding in plugs. Then, connecting bores to the blind bores are drilled from the rear side of the plate body. Thereafter, connection pipe-ends for the coolant feed or coolant return are inserted into these connecting bores and soldered or welded in place. It has recently also been proposed to produce steel cooling plates using the same process. With these cooling plates the above-mentioned disadvantages of casting are avoided. In particular, cavities and porosities in the plate body are virtually precluded.

WO-98/30345 teaches to cast a preform of the cooling plate with the help of a continuous casting mould, wherein rod-shaped inserts in the casting duct produce ducts running in the continuous casting direction, which form coolant ducts in the finished cooling plate. A plate body is separated from the continuously-cast preform by making two cuts transversely with respect to the casting direction, forming two end faces, the distance between which corresponds to the desired length of the cooling plate. In the next production step, connection

bores which open out into the through-passages, are drilled into the plate body perpendicular to the rear surface, and the end-side openings of the cast-in ducts are closed. Thereafter, connection pipe-ends are inserted into the connection bores and soldered or welded in place, as has already been described above.

The manufacturing methods described in DE-A 2907511 and in WO 98/30345 both enable high-quality cooling plate bodies to be produced from copper or copper alloys. However, compared to cooling plates with integrally cast cooling tubes or compared to shape-cast cooling plates, the finished cooling plates produced by both processes have the drawback of having a relatively high pressure loss in the region of the transitions from the connection pipe-ends to the cooling passages.

WO 00/36154 has suggested to reduce the flow losses in copper cooling plates with integrally cast or drilled cooling passages by inserting a shaped piece into a cutout in the cooling plate body, so as to form a diverting passage with optimized flow conditions for the cooling medium. However, this solution is relatively labor-intensive, which is reflected in higher production costs.

DE-A 3313998 discloses a cooling plate for metallurgical furnaces made of a cast iron body. The cooling plate comprises a channel for cooling fluid formed by a steel tube inserted into a bore which extends longitudinally through the body. The steel tube is fixed within the cast iron body at temperature equilibrium by means of a previous shrinkage fit. This solution requires expensive large size shrinkage fit equipment adapted to the dimensions of the cast iron body and the steel tube.

Summary of the Invention

It is an object of the present invention to provide a simple and reliable method of manufacturing cooling plates with relatively low pressure losses. It is another object of the present invention to provide a reliable cooling plate with relatively low pressure losses that can be easily manufactured. These problems are solved by a method in accordance with claim 1, respectively a cooling plate

in accordance with claim 17.

A method of manufacturing a cooling plate in accordance with the present invention comprises the following steps: providing a metallic plate body with a front face, a rear face and at least one channel extending through the metallic plate body beneath its front face; inserting, with radial clearance, a metallic tube into the channel so that both tube ends protrude out of the channel, and achieving a press fit of the tube within the channel. According to an important aspect, the press fit is obtained through a metal-forming process applied to the metallic plate body. This metal-forming process results in shrinking of the section of the channel.

Surprisingly, it has been found that a press fit of the tube in the channel can be obtained in simple, economical and reliable manner by applying a metal-forming process to the blank plate body.

After insertion of the tube, the metal-forming process transforms the metallic plate body into the desired shape for achieving the press fit of the tube within the channel. The metal-forming process includes a permanent mechanical, i.e. plastic deformation of the blank metallic plate body. Possible metal-forming processes are for example forging, pressing or rolling of the metallic plate body. The metal-forming process can convert the plate body from blank condition into the finished condition of the cooling plate. While not excluded, an additional treatment is generally not required to achieve the press fit.

Preferably, the metal-forming process is applied locally along said at least one channel. Local application reduces the required effort or force to produce the press fit and therefore facilitates the machining process and reduces the requirements on the required equipment. For example, the press fit may be achieved by producing a permanent depression along said channel, e.g. on the rear face of the metallic plate body. Alternatively, the entire metallic-plate body may be subjected to the metal-forming process.

In a preferred embodiment of the method, the metal-forming process applied to the metallic plate body provides an elastic deformation of the tube so as to produce a pre-tensioned fit of the tube in the channel. By giving a predeter-

mined extent to the plastic deformation of the metallic plate body, i.e. the region around the channel, a press fit implying a purely elastic deformation of the tube can be achieved. The resulting pre-tensioned fit of the tube within the channel provides increased heat transfer without adverse effects on the physical
5 properties of the tube.

When compared to copper or steel cooling plates having a forged or rolled plate body with drilled conduits for the cooling fluid, respectively to copper cooling plates with a continuously cast plate body in which the conduits for the cooling fluid are cast-in channels, the cooling plates of the present invention
10 have e.g. the following advantages:

- The tubes fitted in the plate body warrant leak tightness, even in case of corrosion, erosion, or cracking of the plate body. It follows that substantial economies may be made on the quality of the plate body.
- Due to the tube ends protruding out of the plate body, there is no ne-
15 cessity to weld connection pipe-ends into the plate body. It follows that a complicated welding operation, requiring highly qualified and experienced man power and involving a leakage risk due to welding defects, is definitely eliminated.
- The tubes with their ends protruding out of the plate body cause a
20 much smaller pressure drop than connection pipe-ends that are welded from the rear face of the plate body into a drilled or cast channel. They also eliminate problems with "dead-ends", such as air pocket and solids accumulations, which are often at the origin of corrosion and flow restriction problems.

25 When compared to cast iron or copper cooling plates cast within a mould, wherein tubes forming the conduits in the finished cooling plates are arranged in the casting mould, the cooling plates of the present invention have e.g. following advantages:

- Because the plate body to be provided may be manufactured on the
30 basis of a rolled, forged or a continuously cast slab, it is relatively easy to reliably produce the required plate body at low costs, free of cavities

and porosities and with a constant quality.

- Because the tubes are not cast into the plate body, it is not necessary to worry about interface problems between the tube material and a liquid plate body material solidifying around the tube.
- 5 - The press fit of the tube within its channel by metal-forming allows to warrant good and constant heat transfer properties between the tube and the plate.

When compared to cast iron cooling plates wherein steel tubes are fixed by shrinkage fit, the cooling plates of the present invention have the advantage
10 of simplified manufacture and in particular of eliminating the need for expensive large size equipment required for shrinkage fitting. Moreover, a press fit resulting in improved heat transfer properties may be obtained by metal-forming.

Consequently, the present invention provides a simple and reliable method of manufacturing cooling plates with relatively low pressure losses,
15 which have many advantages over prior art cooling plates.

In a preferred embodiment of the method, the step of achieving a press fit of the tube within the channel by means of a metal-forming process comprises rolling down the plate body after insertion of the metallic tube in the channel, so as to confer an oval section to the channel and the tube. This metal-forming
20 process has the additional advantage that the metallurgical structure of the plate body is further improved.

In an alternative embodiments, the step of achieving a press fit of the tube within the channel by means of a metal-forming process can comprise forging or pressing of the plate body after insertion of the metallic tube in the channel.

25 In another embodiment of the method, the step of achieving a press fit of the tube within the channel can further comprise expanding the tube by establishing a hydraulic pressure inside the tube.

Optionally, the step of achieving a press fit of the tube within the channel may further comprise expanding the tube with at least one explosion inside.

30 In another possible embodiment of the method, the step of achieving a

press fit of the tube within the channel may further comprise expanding the tube by pulling an expansion head there through.

Additionally, the method may comprise a shrinkage fit of the tube within the channel. This shrinkage fit can be effected prior to achieving the press fit by
5 means of a metal forming process. In this case however, additional equipment is required.

It will be appreciated that it is also possible to successively execute one or more of the above auxiliary steps in combination with the metal-forming process to contribute to the desired press fit of the tube in the channel. The auxiliary
10 steps may be executed prior to the metal-forming process of the plate body or subsequently. In general however, the metal-forming process will be sufficient to achieve the desired press fit without the need for further treatments.

The plate body is normally made of copper or steel. The tube fitted into the channel can e.g. be made of copper or stainless steel. The tube may be easily
15 provided with a coating or lining further improving the heat transfer between the tube and the plate body and avoiding, if necessary, a direct contact between the metal of the plate body and the metal of the tube.

The tube ends protruding out of the channel are advantageously bent towards the rear of the plate body, so as to form a connection pipe-end pointing in
20 a direction substantially perpendicular to a plane parallel to the rear face of the plate body. These connection pipe-ends may then directly pass through connection openings in the furnace shell, i.e. there is no welding or other pipe connection within the furnace. Furthermore, the bent tube ends are able to compensate, at least partially, temperature induced expansion/shrinking of the
25 cooling plate in the furnace, so that no or simpler compensators will be required for connecting the connection pipe-ends to a cooling circuit.

The plate body is advantageously provided with a first perimeter face and an opposite second perimeter face, wherein the at least one channel extends through the metallic plate body so as to form a first opening in the first perimeter
30 face and a second opening in the second perimeter face. This feature warrants a better cooling of the edges of plate body, where the tubes emerge out of the

perimeter faces of the plate body. The perimeter faces are advantageously bevelled towards the rear face of the plate body, so that they form noses protecting the tube ends emerging out of the perimeter faces. To even better protect the tube ends emerging out of the perimeter faces, it is also possible to
5 mill a recess into the perimeter face, so that the recess is open towards the rear face of the plate body and one of the channel openings lies within this recess.

A cooling plate in accordance with the present invention comprises a metallic plate body with a front face, a rear face and at least one metallic tube extending through the metallic plate body beneath the front face so that both
10 tube ends protrude out of the plate body. There is a press fit between the metallic plate body and the at least one metallic tube. According to an important aspect, the plate body is plastically deformed along said channel. It will be appreciated that plastic forming of the blank plate body provides a predominant contribution to the press fit.

15 In a preferred embodiment, the metallic plate body comprises a bulge extending along said at least one channel. The bulge can be provided on the front or the rear face of the plate body, in proximity of the channel along which it extends. The bulge associated to the channel significantly facilitates the metal-forming process, or plastic deformation, of the region around the channel to
20 obtain the press fit. Accordingly, the metal-forming process can be achieved by depression of the bulge with respect to the plate body. In order to further simplify the deformation an aperture is preferably provided within said bulge. In this case, the bulge is preferably located on the rear face of the plate body.

The plate body is advantageously made of copper or steel. The tube is
25 preferably made of copper or stainless steel. It has been found that a combination of a plate body made of steel and a tube made of copper is particularly effective. Each of the protruding tube ends is advantageously bent so as to form a connection pipe-end pointing in a direction substantially perpendicular to a plane parallel to the rear face of the plate body.

Brief Description of the Drawings

Preferred embodiments of the invention will now be described with reference to the accompanying drawings in which:

- Fig. 1: is a longitudinal sectional view of a plate body for manufacturing a cooling plate in accordance with the invention;
- 5 Fig. 2: is a longitudinal sectional view of the plate body of Fig. 1, after having inserted, with radial clearance, a tube into a channel of the plate body;
- Fig. 3: is a longitudinal sectional view of the plate body and tube of Fig. 2, after having achieved a press fit of the tube within the channel;
- Fig. 4: is a longitudinal sectional view of the finished cooling plate;
- 10 Fig. 5: is an alternative embodiment of a cooling plate in accordance with the invention;
- Fig. 6: is a longitudinal sectional view of a plate body with a tube inserted with radial clearance in a channel of the plate body, illustrating the step of expanding the tube with a hydraulic pressure inside to achieve a press
- 15 fit of the tube within the channel;
- Fig. 7: is a longitudinal sectional view of a plate body with a tube inserted with radial clearance in a channel of the plate body, illustrating the step of expanding the tube by pulling a wedge-shaped head there through to achieve a press fit of the tube within the channel;
- 20 Fig. 8: is a partial lateral sectional view of a blank plate body in accordance with a further embodiment;
- Fig. 9: is a partial lateral sectional view of the blank plate body of Fig.8 with a tube inserted with radial clearance in a channel of the plate body;
- Fig. 10: is a partial lateral sectional view of the plate body of Fig.9 in finished
- 25 condition, illustrating the step of shrinking the section of the channel;
- Fig. 11: is a partial lateral sectional view of a blank plate body in accordance with a further embodiment of the invention;
- Fig. 12: is a partial lateral sectional view of the blank plate body of Fig.11 with a tube inserted with radial clearance in a channel of the plate body;

- Fig. 13: is a partial lateral sectional view of the plate body of Fig.12 in finished condition, illustrating the step of shrinking the section of the channel;
- Fig. 14: is a partial lateral sectional view of a blank plate body in accordance with a further embodiment of the invention;
- 5 Fig. 15: is a partial lateral sectional view of the plate body of Fig.14 in finished condition, illustrating the step of shrinking the section of the channel.

Description of a preferred embodiment

Fig. 1 shows a metallic plate body 10 to be used for manufacturing, in accordance with the present invention, a cooling plate (also called stave) to be arranged on the inside of the shell of a metallurgical furnace, e.g. a blast
10 furnace. This plate body 10 has a front face 12, a rear face 14 and four perimeter faces. Two of these four perimeter faces are identified with reference numbers 16, 18, whereas the other two perimeter faces are not seen in the sectional view of Fig. 1. The two perimeter faces 16 and 18 are bevelled towards the rear face 14 of the plate body 10. The front face 12, which is
15 exposed to the interior of the furnace, is advantageously provided with grooves 20, which increase the cooling surface and improve adherence of a refractory lining. Reference number 22 identifies a straight, cylindrical channel 22, which extends through the metallic plate body 10 beneath the front face 12 so as to form openings 24, 26 in the perimeter faces 16 and 18. The section of the
20 channel is normally circular, but an oval section is not excluded. The plate body 10 includes several of such channels 22, which are normally all parallel to one another.

Such a plate body 10 is e.g. manufactured from a forged or rolled slab made either of copper, a copper alloy or steel, wherein channels 22 are drilled
25 into the forged or rolled slab. Alternatively, the plate body 10 may also be manufactured from a continuously cast copper or steel slab, wherein the channels 22 are produced by rod-shaped inserts during the continuous casting operation, such as described e.g. in WO-98/30345. Thereafter, the cast-in channels can still be machined with a metal-cutting tool so as to improve their
30 dimensional and form tolerances.

In accordance with the present invention, the channel 22 is not designed to form itself a conduit for the cooling fluid (normally cooling water), but to house a metallic tube 30 that forms the conduit for the cooling fluid. As shown in Fig. 2, this metallic tube 30, which is preferably made of copper, a copper alloy or stainless steel, is inserted with radial clearance into the channel 22, so that both tube ends 32, 34 protrude from the channel 22. A preferred combination consists in a plate body 10 made of steel and a tube 30 made of copper. After insertion of the tube 30 into the plate body 10, one achieves a press fit of the tube 30 within the channel 22, by shrinking the section of the channel 22 (i.e. by transforming the initial clearance fit into an interference fit) by means of a metal-forming process applied to the plate body 10. This press fit warrants a close contact between the external wall of the tube 30 and the internal wall of the channel 22, which results in a good heat exchange between the plate body 10 and the tube 30. Fig. 3 shows the plate body 10 with the tube 30 after having achieved a press fit of the tube 30 within the channel 22.

The desired press fit of the tube 30 in the channel 22 of the plate body 10 is obtained by a metal-forming process applied to the plate body 10. Additionally one or more pre- or post treatments may be applied as detailed below.

In accordance with a first embodiment of the method, the sections of the channel 22 and the tube 30 are dimensioned so as to have radial clearance of the tube 30 in the channel 22 when the plate body 10 and the tube 30 are both at ambient temperature. After having introduced the tube 30 into the channel 22 of the plate body 10, the plate body 10 is rolled down. Thereafter, the originally cylindrical tube 30 has an oval section and a press fit of the tube 30 in the channel 22 is achieved.

Example:

Tube diameter: 69,9-70,1 mm (at 20 °C)

Channel diameter: 70,3-70,8 mm (at 20 °C)

Rolling down the plate by 1 mm will be sufficient to achieve a press fit of the tube 30 in the channel 22. The section of the tube 30 will become slightly oval.

Since the extent to which the complete plate body 10 can be rolled down has a certain upper limit, additional steps may be applied as pre- or post treatments in order to support the press fit obtained by rolling of the plate body 10. A number of such additional steps are described below.

5 In a first additional step which is illustrated in Fig. 6, the sections of the channel 22 and the tube 30 are also dimensioned so as to have a radial clearance (i.e. positive allowance) of the tube 30 in the channel 22 when the plate body 10 and the tube 30 are both at ambient temperature. After having introduced the tube 30 into the channel 22 of the plate body 10, a conical
10 expansion head 40 is pulled through the tube 30 by means of a hydraulic cylinder 42. This expansion head 40 expands the section of the tube 30 and thereby prepares a press fit of the tube 30 in the channel 22 by subsequent metal-forming of the plate body 10. While described as pre-treatment, the mechanical tube expansion may also be effected after rolling of the plate body
15 10.

In accordance with another additional step, which is illustrated in Fig. 7, the sections of the channel 22 and the tube 30 are again dimensioned so as to provide a radial clearance (i.e. positive allowance) of the tube 30 in the channel 22 when the plate body 10 and the tube 30 are both at ambient temperature.
20 After having introduced the tube 30 into the channel 22 of the plate body 10, the tube 30 is expanded by means of a pressurized hydraulic fluid pumped into the tube 30. The device shown in Fig. 7 comprises a head 50 that is put in a sealed manner onto one end of the tube 30. This head 50 comprises a rod 52 that extends through the tube 30 to support a plug 54, which seals off the tube 30
25 near the opposite outlet of the channel 22. A channel 56 allows to pump the pressure fluid into tube 30. The hydrostatic expansion of the tube 30 contributes to a subsequent press fit of the tube 30 in the channel 22 by metal-forming of the plate body 10. While described as pre-treatment, such hydrostatic expansion may also be effected after rolling of the plate body 10.

30 In accordance with yet another additional step, a shrinkage fit of the tube 30 in the plate body 10 may be effected prior to the metal-forming process. In a

manner known per se, the sections of the channel 22 and the tube 30 are dimensioned with a radial interference at temperature equilibrium. Before inserting the tube 30 into the channel 22, a radial clearance is produced by heating the plate body 10 and/or cooling the tube 30. After insertion of the tube 5 30, a radial interference is obtained when returning to temperature equilibrium. Consecutively, a metal-forming process applied to the plate body will achieve the desired press-fit.

It is of course possible to execute one or more of the above auxiliary steps to contribute to the desired press fit of the tube 30 in the channel 22. In general, 10 the metal-forming process applied to the plate body 10 will however be sufficient to achieve the desired press fit.

Fig. 4 shows a finished cooling plate manufactured with the plate body 10 shown in Fig. 1. After having achieved the desired press fit of the tube in the channel 22 of the plate body 10, the tube ends 32, 34 protruding from the 15 bevelled perimeter faces 16, 18 are bent towards the rear of the plate body 10, so as to form a connection pipe-end 60, 62 pointing in a direction substantially perpendicular to a plane parallel to the rear face 14 of the plate body 10. It will be noted that the bevelled perimeter faces 16, 18 form noses 64, 66, which cooperate to protect the bent tube ends 32, 34 towards the interior of the furnace.

20 Fig. 5 shows a finished cooling plate manufactured on the basis of a plate body 10' having a slightly different design than the plate body 10 of Fig. 1. In this plate body 10', each channel end opens into a recess 70, 72 that is milled into a perimeter face 16', 18' of the plate body 10', so as to be open towards the rear face 14' of the plate body 10'. Towards the front face 12', each of the 25 recesses 70, 72 is closed by a residual plate portion 74, 76. Protected by the residual plate portions 74, 76 towards the front side of the cooling plate, the bent tube ends 32', 34' form connection pipe-ends 60', 62' pointing in a direction substantially perpendicular to a plane parallel to the rear face 14' of the plate body 10'.

30 Another preferred embodiment for manufacturing a cooling plate is described below. This embodiment overcomes the limitation on the extent to which

the thickness of the plate body 10, 10' can be reduced by rolling of the complete plate body 10, 10'.

Fig. 8 shows a blank plate body 10" according to an alternative embodiment for manufacturing a cooling plate. Fig. 8 is a partial lateral sectional view of the plate body 10" in the region of a channel 22. The channel 22 may be cast-in or drilled as detailed above. The plate body 10" is provided on its rear face 14 with a bulge 80. The bulge 80 extends along the channel 22, in a direction perpendicular to the plane of Fig. 8. The bulge 80 is arranged proximal to and above the location of the channel 22. The bulge 80 is normally produced with the plate body 10" during the manufacturing of a forged or rolled slab or during the continuous casting of a copper or steel slab. Alternatively, the bulge may be produced in a subsequent step, e.g. by build-up welding. It may be noted that multiple bulges are normally provided on the rear face 14 of the plate body 10" i.e. one for each channel 22 (not shown).

Fig. 9 shows the plate body 10" of Fig.8 with a tube 30 inserted into the channel 22 with radial clearance. The radial clearance is preferably present at temperature equilibrium between plate body 10" and tube 30 by corresponding dimensioning of the latter.

Fig.10 shows the plate body 10" and the tube 30 of Fig.9 after a metal-forming process applied to the plate body 10" and more specifically to the bulge 80. After insertion of the tube 30, the bulge 80 is depressed, e.g. through a rolling or pressing process. The metal-forming process is normally applied locally to the bulge 80 such that the top of the bulge 80 is forced towards the channel 22, i.e. vertically downwards in Fig.9. The mechanical transformation flattens the rear surface 14 so as to force the initial bulge 80 permanently into the plate body 10" as shown in Fig.10. The section of the channel 22 is thereby reduced so as to transform the initial radial clearance into a press fit between the tube 30 and the plate body 10". As further seen in Fig.10, the originally cylindrical tube 30 and channel 22 have a slightly oval section after the transformation.

The thickness and shape of the bulge 80 in Figs. 8 and 9 will be chosen

such as to achieve a determined permanent plastic deformation of the region of the plate body 10" proximal to the bulge 80 and the channel 22. This plastic deformation of the plate body 10" preferably results in an elastic deformation of the tube 30. A pre-tensioned fit of the tube 30 in the channel 22 is thereby achieved. It will be appreciated that the initial bulge 80 significantly facilitates the step of metal-forming the plate body 10" to produce a press fit. In particular, the bulge 80 eliminates the need to roll down the entire plate body 10" to achieve a press fit and increases the extent to which the section of the channel 22 can be reduced.

Fig. 11 shows a blank plate body 10" according to a further embodiment of manufacturing a cooling plate. Compared to Fig.8, the plate body 10" comprises a similar bulge 80 which is however provided with an aperture 82. The aperture 82 may be obtained by incision or, alternatively, may be cast-in. In a direction parallel to the plane of Fig. 11, the aperture 82 extends through the bulge 80 from the rear face 14 into the channel 22 so as to form two shoulders 84 and 84' within the bulge 80. In a direction parallel to the plane of Fig. 11, the aperture 82 normally extends over the length of the bulge 80. The width of the aperture 82 preferably decreases towards the channel 22.

Fig. 12 shows the plate body 10" of Fig.11 with a tube 30 inserted with radial clearance into the channel 22.

Fig. 13 shows the plate body 10" in a finished condition. Compared to Fig. 12, the tube 30 is press fit within the channel 22 after a metal-forming process applied to the plate body 10", more specifically to the shoulders 84 and 84'. The region of the plate body 10" around the channel 22 is plastically deformed, e.g. by rolling, in order to achieve the press fit of the tube 30 in the channel 22. The shoulders 84 and 84' are permanently bent down and joined so as to pinch the tube 30. The initial aperture 82 is thereby closed, as seen in Fig.12. As will be appreciated, the initial aperture 82 facilitates the metal-forming process by reducing the required effort for depressing the bulge 80. The same effect can be achieved if the initial aperture 82 is not fully closed. Depending on the initial aperture size, a slit can remain along the channel 22,

without significant negative effect on the finished cooling plate. Except for the interrupted bulge 80, the finished plate body 10'' of Fig.13 has similar properties and advantages as the finished plate body 10'' of Fig.10.

Fig. 14 shows a blank plate body 10 according to a further embodiment for manufacturing a cooling plate. When compared to Fig. 8 or Fig. 11, the blank plate body 10 is not provided with a bulge 80. Fig. 14 shows the plate body 10 with a tube 30 already inserted with radial clearance into the channel 22.

Fig. 15 shows the plate body 10 of Fig. 14 in finished condition. The plate body 10 has been subjected to a metal-forming process producing a local depression 90. The metal-forming process for producing the depression 90 may be a rolling or pressing operation. The depression 90 is provided locally on the plate body 10, i.e. in proximity of and along the channel 22. Accordingly, the depression 90 extends along the channel 22 in a direction perpendicular to the plane of Fig. 15. The depression 90 reduces the section of the channel 22 when compared to Fig. 14. As a result, a press fit of the tube 30 in the channel 22 is achieved. The extent by which the plate body 10 is depressed, i.e. the height of the depression 90 is normally chosen such as to obtain a determined plastic deformation of the region around the channel 22 of the plate body 10. This determined plastic deformation preferably results in an elastic deformation of the tube 30 whereby a pre-tensioned fit of the latter within the channel 22 is warranted.

As will be appreciated, the method in accordance with Figs. 8-10; Figs. 11-13 or Figs. 14-15 will result in finished cooling plates having essentially the same properties as those described in relation with Fig.4 and Fig.5.

When compared to copper or steel cooling plates having a forged or rolled plate body with drilled conduits for the cooling fluid, respectively to copper cooling plates with a continuously cast plate body in which the conduits for the cooling fluid are cast-in channels, the above cooling plates have e.g. following advantages:

- high quality copper or stainless steel tubes 30, 30' may be used, which warrants leak tightness for many years, even in case of corrosion, ero-

sion, or cracking of the plate body 10, 10';

- as the plate body 10, 10' does not have to warrant water tightness, substantial economies may be made on the quality of the plate body 10, 10', which allows to compensate the expenses for high quality copper or stainless steel tubes 30, 30' by far;
- no necessity to weld connection pipe-ends into the plate body 10, 10', which eliminates an operation that requires highly qualified and experienced man power and always involves a leakage risk due to welding defects;
- the tubes 30, 30' with their bent ends 32, 34, 32', 34' cause a much smaller pressure drop than connection pipe-ends that are welded into a drilled or cast channel;
- the tubes 30, 30' with their bent ends 32, 34, 32', 34' eliminate problems with "dead-ends", such as air pocket and solids accumulations, which are often at the origin of corrosion and flow restriction problems;
- better cooling of the edges of plate body 10, 10', because the tubes 30, 30' emerge out of the perimeter faces 16, 18, 16', 18' of the plate body 10, 10';
- the bent tube ends 32, 34, 32', 34' are able to compensate, at least partially, temperature induced expansion/shrinking of the cooling plate in the furnace, so that no or simpler compensators will be required for connecting the connection pipe-ends 60, 62, 60', 62' to a cooling circuit.

When compared to cooling plates that are cast within a mould, wherein tubes forming the conduits for the cooling fluid are directly cast-in, the above cooling plates have e.g. following advantages:

- because the plate body 10, 10' may be manufactured on the basis of a rolled, forged or continuously cast slab, it is relatively easy to achieve the plate body 10, 10' free of cavities and porosities;
- slabs for manufacturing the plate body 10, 10' may be industrially produced at low costs and with a constant quality;

- it is not necessary to worry about interface problems between the tube material and a plate material solidifying around the tube;
- the press fit of the tube 30 within the channel 22 allows to warrant good and constant heat transfer properties between the tube 30 and the plate 10, 10'.

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